Cortisol and Executive Functioning for Young Children attending Head Start Preschool

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Cortisol and Executive Functioning for Young Children attending Head Start Preschool

A Dissertation Project

Presented to the Faculty of the

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By

Zachary Weaver, MS

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Abstract

Poverty circumstances impact the hypothalamic-pituitary-adrenal or HPA axis. Early childhood dysfunction in the HPA axis, marked by irregularities in cortisol, poses risk for the development of key executive functioning (EF) abilities. No studies have investigated the relation between cortisol and performance-based measures of EF in settings such as Head Start preschool that aim to promote positive outcomes for children facing economic hardship. This pilot study examined EF and cortisol for 50 children ages 3 to 5 years, who attended a Head Start preschool. This study was disrupted by the COVID-19 pandemic, which led to a sample size less than half of what was suggested by power analyses. EF was measured by performance-based measures and salivary cortisol samples were obtained at 5 time points across two days near the start of the preschool year. Cortisol output across the preschool day was computed using the standard Area Under the Curve with Respect to Ground formula and several profiles of cortisol production across the day were coded. Given limited statistical power, findings from this pilot study must be interpreted with caution. Inferential results did not demonstrate statistically significant relations between these representations of cortisol and EF but did show some expected relations linking demographic variables to cortisol and EF. Moreover, descriptive results provide meaningful information regarding cortisol and EF within the context of Head Start. This pilot study contributes a foundation for future studies examining cortisol and EF for children facing economic hardship. Implications concern understanding poverty risk and informing intervention and programming.
# Table of Contents

List of Tables.............................................................................................................iv  
List of Figures..........................................................................................................v  
Chapter 1: Introduction............................................................................................1  
Chapter 2: Literature Review..................................................................................2  
Chapter 3 Method..................................................................................................18  
Chapter 4: Results..................................................................................................25  
Chapter 5: Discussion............................................................................................28  
References.............................................................................................................50
List of Tables

1. Means and Standard Deviations for Cortisol Samples By Collection Time Point…..46
2. Independent Samples t-tests for Cortisol Groups on IC Composite Scores…………47
3. Independent Samples t-tests for Cortisol Groups on WM Composite Scores……..48
List of Figures

1. Cortisol Levels Across the Preschool Day......................................................49
Chapter 1: Introduction

Early childhood poverty is pervasive in the US, with almost a fourth of all children under the age of 6 years living in households classified as impoverished (Jiang et al., 2016). Children growing up in poverty face risk for difficulties with learning and school achievement, as well as social-emotional functioning. Recent research highlights the explanatory role of executive functioning (EF), or the ability to: actively remember instructions; focus on new, task-relevant cognitive challenges; and inhibit inappropriate behavior (Fitzpatrick, 2014). Exposure to poverty-related stress matters centrally to the development of EF, as stress hormones exert influence on concurrent functioning as well as the development of related brain areas such as the prefrontal cortex. Yet much remains to be learned about the impact of stress on EF, particularly within preschool contexts. The present study examined the stress-related hormone cortisol in relation to EF performance for young children attending Head Start preschool. Implications concern designing effective interventions and programs for young children facing poverty-related stress.
Chapter 2: Literature Review

Poverty and Child Development

Childhood poverty is associated with physical health difficulties, including an increased risk of experiencing a range of illnesses and physical disabilities (Duncan & Brooks-Gunn, 2000). Economic hardship is also associated with emotional dysregulation and disruptive behavior in preschool contexts (Raver et al., 2009). Additionally, economic hardship during childhood is associated with risks to cognitive functioning and academic performance. Young children in the lowest socioeconomic group score 60% lower on tests of cognitive abilities than children from higher SES backgrounds (e.g., Lee & Burkam, 2002), and are more likely to be diagnosed with a specific learning disorder, repeat a grade, or drop out of high school (Duncan & Brooks-Gunn, 1997). Recent research highlights the importance of executive functioning (EF) for explaining disparities in social-emotional as well as academic outcomes for children facing economic hardship (Blair & Raver, 2016).

Executive Functioning

EF is a higher order cognitive system comprised of multiple interrelated yet partially dissociable abilities (Miyake, 2000) such as working memory, emotion regulation, attention, cognitive flexibility and the inhibition of inappropriate or impulsive behavior (Miyake, 2001). Moreover, EF is believed to influence important aspects of information processing such as fluency, speed of processing, organizing, and planning (Carlson & Moses, 2001). These skills are crucial for adaptive and goal-directed behavior (Kolb & Wishaw, 1998; O’Toole, 2017), and academic success (Best et al., 2011; Blair & Razza, 2007; Welsh et al., 2010). In the classroom, EF enables children to hold an instruction in mind during an educational activity (working memory), while simultaneously focusing on novel stimuli relevant to problem-solving tasks.
(cognitive flexibility) and resisting external or internal distractions (emotion regulation and inhibitory control) (Fitzpatrick et al., 2014).

During early childhood, EF shows rapid development (Garon et al., 2008), and the extent of this growth predicts the acquisition of pre-academic skills for children facing economic hardship (Blair & Razza, 2007; Fitzpatrick et al., 2014; Welsh et al., 2010). Blair & Razza (2007) demonstrated a significant link between self-regulatory aspects of EF such as inhibitory control and the development of foundational literacy and numeracy skills in children from low-income households. Additionally, Welsh and colleague’s (2010) examination of the development of attention and working memory aspects of EF over the course of a Head Start preschool year found these abilities to be statistically significant predictors of numeracy and literacy skill development across the year as well as in the following kindergarten year.

Moreover, research has shown that multiple aspects of EF (e.g., working memory, cognitive flexibility, inhibitory control, and attention shifting) predict variance in preacademic school readiness that is unique from that predicted by measures of general intelligence and processing speed (Fitzpatrick et al., 2014). The development of EF during early childhood also holds importance for socialization and relationship building within preschool contexts. O’Toole and colleagues (2017) found that performance on measures of EF predicted prosocial behavior and the quality of friendships throughout a preschool year within a heterogenous family income level sample.

Unfortunately, children facing economic hardship consistently score below their middle- and high- income peers on tests measuring various aspects of EF (Fitzpatrick et al., 2014), and both the chronicity and intensity of early childhood poverty pose greater risk for the development of these skills (Raver et al., 2013). Raver and colleagues (2013) conducted a longitudinal study
that followed a large sample of young children living in low-income households from age 7 months through 4 years, and found that duration of time spent in poverty, severity of poverty, and high parental financial strain significantly predicted poorer EF on performance-based measures of working memory, cognitive flexibility and inhibitory control.

Understanding the impact of poverty on executive functioning requires consideration of contextual risks such as neighborhood violence and instability within the home (Evans, 2004), which disrupt the proximal processes or exchanges between the child and their immediate environment (Bronfenbrenner, 1989) that are supportive of EF development (Fiese & Winter, 2010). Research has demonstrated that family instability and chaotic living conditions (physical and psychosocial) are linked to poorer self-regulatory aspects of EF such as inhibitory control in children facing economic hardship (Brown et al., 2013; Evans, 2002). In addition to disrupting proximal processes that allow children to develop and practice learning skills, poverty-related contextual risk factors likely impact the development of the physiological stress response system as well as brain areas involved in executive functioning (Ackerman & Brown, 2010; Evans, 2002). Emergent research suggests that the link between childhood economic hardship and EF difficulties is partially explained by dysregulation in the hypothalamic-pituitary-adrenal (HPA) axis and associated atypical neurodevelopment (Blair & Raver, 2016; Evans & Kim, 2013).

**The HPA System**

The HPA axis is a main component of the physiological stress-response system and activity in the HPA axis during early childhood holds substantial importance for lifelong, neurophysiological development (Gunnar & Quevedo, 2007). Under typical environmental conditions, increased short-term activity in the HPA axis in response to stress or challenge is adaptive, as it promotes binding between cortisol and glucocorticoid receptors and the allocation
of cellular energy to the prefrontal cortex (Arsten, 1998), which facilitates cognitive and behavioral responses to challenging stimuli (Sapolsky, 1996). However, early developmental environments that are chronically aversive or stressful such as the context of early childhood poverty, can overtax physiological stress response systems (McEwen, 2013) and lead to dysregulation in the HPA axis (Blair & Raver, 2016). Dysregulation in the HPA axis is associated with synaptic suppression in the prefrontal cortex or PFC (Joels & Baram, 2008), which poses critical risk for the development of this brain region as it is undergoing a period of rapid growth or synaptogenesis throughout early childhood (Coley et al., 2015).

Broadly, the function of the PFC, which works in conjunction with the premotor cortex and limbic system is described as temporal organization, which is the ability to engage in goal-oriented behavior and cognitive planning while ignoring unnecessary external stimuli (Kolb & Wishaw, 2009). A robust body of research, including studies utilizing fMRI and neuroimaging techniques, have localized EF skills to the PFC (Miller & Cohen, 2001). Findings from recent neuroimaging studies have demonstrated SES-related structural disparities in PFC development (Hair et al., 2015; Hanson et al., 2013) which can be partially attributed to HPA axis dysregulation (Blair & Raver, 2016). Hair and colleagues (2015), for example, examined a cross-sectional sample of children and young adults ranging from ages 4 to 22 years, and demonstrated that individuals in poverty experience an 8 to 9 percent reduction in overall gray matter within the PFC throughout development in comparison to upper- and middle- SES individuals. Evidence suggests that when this relationship is examined throughout infancy and toddlerhood, disparities in gray matter between children of differing SES are even greater (Hanson, et al., 2013).
Activity in the HPA axis is most frequently measured via its end-product, cortisol, which is a primary glucocorticoid and can be obtained noninvasively through the sampling of hair or saliva (Kronenberg, 2007). Cortisol is influenced by the circadian light/dark cycle and typically follows a diurnal profile across the day which includes an early morning elevation followed by a gradual decrease from midmorning throughout the rest of day (Pruessner et al., 1997). Basal cortisol or the cortisol awakening response promotes an array of functioning including metabolism, immune support, memory and learning (Arsten, 1997). Cortisol secretion elevates in response to experiences of stress, and these increases are superimposed onto baseline levels of cortisol (McEwen, 1998). Additionally, fluctuations in the typical diurnal trajectory of cortisol are associated with factors such as socioeconomic status and environmental stressors (Fries et al., 2009; Lupien et al., 2000).

**The Impact of Poverty on HPA Axis Functioning and Cortisol**

A robust literature has documented that extended or repeated exposure to environmental stressors can lead to dysregulation in HPA axis and cortisol functioning, which can manifest as hyper- or hypocortisolism (Slopen et al., 2014). Hypercortisolism in the organism is characterized as chronically elevated basal cortisol and heightened response or reactivity to acute stressors, whereas the latter is the opposite (Lupien et al., 2001). Experiences of hypercortisolism versus hypocortisolism in the individual are dependent upon developmental considerations, and the severity, nature and duration of stress exposure (Lupien et al., 2009). Although it may manifest differently, dysregulation in the HPA axis poses risk for an array of psychological and physical concerns regardless of the direction of cortisol production (McEwen, 2013).

Dysregulation in HPA functioning most consistently manifests as hypercortisolism for children facing economic hardship in the United States (Blair et al., 2011; Evans & Kim, 2012;
McEwen, 2013). For example, Blair and colleagues (2011) linked income and poverty-related risks to elevated basal cortisol in a large sample of children, studied longitudinally from age 7-months to 4 years. Moreover, findings from Evans and Kim (2012) demonstrate similar results in school age children and adolescents. However, a subset of children who have experienced acute trauma or severe or chronic poverty-related stress show hypo-reactivity to stressors and depressed basal cortisol (Gunnar & Cheatham, 2003; Gunnar & Vazquez, 2001). Additionally, previous research has demonstrated low basal cortisol for African American children facing multiple poverty-related risks (Kliwer et al., 2009), and associations between experiences of maternal depression, maltreatment/neglect and hypocortisolism (Fernald et al; 2008; Gunnar & Vazquez, 2001). Roisman and colleagues (2009) linked these findings to the attenuation hypothesis (Susman, 2006), which contends that exposure to significant stressors and subsequent hypocortiolism is likely preceded by hypersecretion of cortisol.

Bevans and colleagues (2008) have linked decreased adrenocortical secretion to frequent elevations in cortisol as a result of chronic exposure to significant stress during early childhood. Moreover, research utilizing genome-wide transcriptional profiling found associations between low SES in childhood and elevated adult cortisol, up-regulation of genes related to adrenergic neural reception, and down-regulation of genes that are important for glucocorticoid reception (Miller et al., 2009). These findings demonstrate that experiences of childhood poverty can alter the physiological equilibrium or the process of allostasis of individuals through HPA axis dysregulation, which can lead to lifelong alterations in the physiological stress response system, along with other, associated negative physical and psychological outcomes (Chen et al., 2010).

Cortisol and EF
A robust literature documents the impact of early childhood economic hardship on EF (Fitzpatrick et al., 2014; Raver et al., 2013) and HPA axis dysregulation (Evans & Kim, 2012; Gunnar & Vazquez, 2001), which poses risk for the prefrontal cortex (PFC) and associated EF development (Blair & Raver, 2016; Joels & Baram, 2009). However, few studies have examined the relationship between cortisol and performance on EF measures in children from low SES households. Blair, Raver and colleagues (2011, 2013, 2017) examined 1,292 low-income children from urban and rural populations’ performance on measures of working memory and inhibitory control aspects of EF at five different time points between infancy and the age of 4, in relation to basal cortisol levels as measured by saliva sampling at baseline (prior to engaging in EF tasks) during the morning of each home visit. Results revealed that higher basal cortisol significantly mediated the relationship between poverty severity and poorer performance on EF tasks at each time point (Raver, et al., 2017). Additionally, a study by Wagner and colleagues (2016) linked elevated basal cortisol to lower parent-reported EF and higher parental stress in low SES preschoolers. Lastly, a recent study published by Brown and colleagues (2023) demonstrated relations between high basal cortisol across the preschool day to greater teacher-reported EF difficulties.

In addition to examining the relationship between basal cortisol and EF performance, a study by Blair and colleagues (2005) linked important aspects of cortisol reactivity to performance on teacher ratings of EF in low-income preschool settings (Blair et al., 2005). This study measured children’s cortisol reactivity over the duration of a 45-minute testing session and found that it significantly predicted teacher reports of self-regulation. Results revealed that typical cortisol reactivity or slight increases in cortisol production followed by down-regulation in response to challenge predicted higher teacher-reported self-control and attention (Blair et al.,
2005), whereas atypical reactivity or diminished cortisol production or increases in production that were not followed by down-regulation predicted more teacher-reported difficulties in these aspects of EF.

A number of studies speak to the impact of cortisol dysregulation on constructs that relate to EF, such as externalizing behavior. Smider and colleagues (2002), for example, conducted a study of cortisol reactivity and constructs such as externalizing behavior and school engagement, and found that higher levels of afternoon cortisol predicted higher parent-reported externalizing behavior and teacher-reported difficulties with school engagement during the following academic year. Other studies have demonstrated that dysregulation in basal cortisol relates to externalizing behavior and emotion dysregulation (Hart et al., 2005; Kariyawasam et al., 2002). Notably, the pattern of associations has been mixed (Alink et al., 2008). Hart and colleagues (2005), for example, found that higher basal cortisol related to externalizing behavior, as measured by the Child Behavior Checklist—Direct Observation Form (Achenbach, 1986). Other studies, however, have demonstrated associations between lower cortisol and externalizing behavior or aggression (Kariyasam et al., 2002; McBurnett et al., 1996). For example, McBurnett and colleagues (1996) found that depressed basal cortisol was associated with aggressive behavior in youth (age 7-12) referred for conduct-related concerns. The mixed findings attest to the complexity of HPA-behavior relations and support the notion that such relations depend on developmental timing and context.

When the present study was proposed, we knew of no published studies to date that had examined cortisol across the preschool day in relation to EF (see for exception Brown et al., 2023). Measuring cortisol across the day accounts for the sensitivity and intensity of cortisol secretion profiles, in addition to basal levels (Fekedulgen et al., 2007). Studies documenting the
relationship between EF and cortisol for children facing economic hardship have either included measurements of basal cortisol collected in home contexts in the morning prior to assessing children (Blair et al., 2011, 2013; Wagner, 2011) or immediate cortisol reactivity in response to moderate stress as measured by collection following a cognitively or socioemotionally challenging task (Blair et al., 2005). Examining the relationship between cortisol and EF in young children in either of these fashions may miss important alterations in the development of the physiological stress-response system that are particularly impactful for PFC and EF development. For example, previous research has demonstrated depressed levels of basal cortisol and diminished cortisol reactivity in children who have experienced severe poverty or trauma (Gunnar & Vazquez, 2001), which poses significant risk for PFC development (Joels & Baram, 2009; McEwen, 2013), yet previous research has not been designed to assess the relation between various markers of HPA axis functioning and compromised EF, such as depressed basal cortisol, blunted cortisol reactivity, and regulation of cortisol across the day. Moreover, fluctuations in HPA activity across the day that may exacerbate dysregulation are influenced by immediate environmental contexts including that of early childhood education (Lupien et al., 2009). Measuring production across the preschool day would be important for answering critical questions regarding the relation between HPA activity marked by various indicators of cortisol production and EF in key early intervention settings such as Head Start.

Cortisol and Preschool Contexts

Head Start represents the United States main investment in early intervention for children in poverty and aims to promote a variety of lifelong positive outcomes and shrink the income-achievement gap (Zigler & Valentine, 1979). Broadly, Head Start preschool programs focus on facilitating pre-academic learning through teaching foundational literacy and numeracy skills in
full-day classroom settings (Raver et al., 2008). Head Start and related preschool programs promote positive development, such as school readiness prior to kindergarten entry but fall short of equalizing educational outcomes for children facing economic hardship in the long-term (U.S. Department of Health and Human Services, 2010). Recent research has identified that SES disparities in EF performance in early childhood likely play a key role in explaining educational outcomes (Blair et al., 2018; Fitzpatrick et al., 2014; Vietello et al., 2011). Although a wealth of research provides evidence that HPA axis dysregulation specific to childhood poverty impacts EF development, few studies to date have focused on cortisol and EF in this context (see Blair, Granger & Razza, 2005, for an exception).

Blair and colleagues (2011, 2013) assessed basal cortisol in relation to EF in home-settings of children from low SES families and operated under the notion that elevations in basal cortisol were superimposed on a typical diurnal trajectory, with specific implications for EF development. This assumption most likely made sense for the home context. However, notably, full day childcare settings such as preschool have been shown to alter the typical trajectory of cortisol across the day (Vermeer et al., 2006; Watamura et al., 2010). Vermeer and Ijzendoorn’s (2006) conducted a meta-analysis that demonstrated that children in early educational childcare settings show gradual increases in cortisol from midmorning to midafternoon, whereas children in home settings show a typical decrease in cortisol across this time interval. Further studies have extended this finding to preschool contexts (Watamura et al., 2010).

Fluctuations in typical cortisol trajectories across the day in preschool contexts are thought to be influenced by academic, as well as social challenges in particular (Watamura et al., 2003). In fact, greater elevations in cortisol from midmorning to midafternoon are associated with environmental factors in preschool settings such as, larger group contexts (Rappolt-
Schlichtmann et al., 2009), and higher child to teacher ratios (Sajaniemi et al., 2011). Research has also demonstrated that positive child-teacher relationships are associated with more typical cortisol production across the day in middle SES preschoolers (Hatfield, 2019). However, it is unclear in the current literature as to whether similar alterations in typical cortisol trajectories occur in preschool contexts for children in poverty, and further research in this area is imperative for guiding policy and practice (Hatfield, 2019).

Findings from a study by Watamura and colleagues (2010) suggest that elevations in cortisol from midmorning to midafternoon in preschool settings are consistent across SES groups. In contrast, findings from other studies have indicated that children facing particular poverty-risk, such as high levels of home chaos or instability may show a more typical decrease in cortisol over this time interval in Head Start contexts (Eliassan et al., 2012). Eliassan and colleagues (2012) postulated that children facing particular poverty risk may feel moderate relief from stress in preschool contexts, despite social challenges. For example, Berry and colleagues (2014) examined poverty-related contextual factors in relation to the impact of childcare across early childhood (7 to 36 months) on basal cortisol measured at 48 months. Results indicated that greater weekly hours of childcare are associated with higher cortisol in children facing low poverty risk, whereas the opposite is true for children facing multiple risk factors (Berry et al., 2014). Additionally, research examining cortisol across the preschool day for low SES children indicated a significant positive association between income and basal cortisol (Zalewski et al., 2012). Zalewski and colleagues (2012) also found that cumulative poverty risk predicted atypical cortisol trajectories, whereby children facing greater poverty-risk showed a flattened trajectory across the preschool day. Importantly, the quality of childcare settings and relationships with teachers as well as caregivers should be considered in addition to specific poverty-risk (Rappolt-
Schlichtmann et al., 2009). Findings from Rappolt-Schlichtmann and colleagues (2009) indicated that high quality childcare and lower levels of relationship conflict are associated with typical decreases in cortisol across midmorning in low SES children. Understanding more about how the context of preschool impacts cortisol across the day for children facing economic hardship represents a critical need as preschool represents a key context for early intervention, and atypical cortisol production holds significant implications for the development of EF (Blair et al., 2011, 2013) and related educational outcomes for these children at risk (Welsh et al., 2010).

The impact for EF of various profiles of cortisol production across the preschool day is unclear. Findings that demonstrate associations between hypercortisolism and compromised EF, would suggest that a combination of high basal cortisol and elevations across the day unique to preschool contexts may particularly undermine concurrent EF and children’s development of EF skills over time. Additionally, given that increases in cortisol followed by down-regulation are important for EF performance in early intervention preschool contexts (Blair & Razza, 2005), the combination of depressed basal cortisol and diminished cortisol reactivity across the preschool day may also undermine EF. Alternatively, if children’s typical cortisol functioning is shaped mostly by their early home environments, and if preschool poses only short-term and mild challenge for this system, or even offers a respite from stressors at home, then basal cortisol across the preschool day may not predict EF competencies that have been developing over the course of several years prior to preschool entry.

Furthering the understanding of cortisol production across the preschool day, and its impact on EF is critical for the design of early intervention programs. Building upon this understanding will allow early intervention programs to position themselves to promote EF and related positive educational outcomes through addressing physiological stress. A major goal of
Head Start early intervention is to promote the development of self-regulatory EF skills in the service of learning and long-term academic success (Ursache et al., 2011). Studies from Raver and colleagues (2011) regarding the implementation of the Chicago School-Readiness Program, demonstrate that targeting self-regulation via teacher-training in low-income preschool classrooms is effective in promoting preacademic skill development. However, a meta-analysis conducted by Diamond and colleagues (2015), concluded that further research is needed to understand the effectiveness of such interventions on long-term improvements in EF and academic achievement. Examining cortisol across the preschool day in relation to EF will aid this endeavor as chronically elevated or depressed cortisol production in response to challenge may limit the effectiveness of these programs. Meanwhile, various preschool interventions have been shown to reduce child cortisol levels. For example, Brown et al. (2016) demonstrated that arts-integrated preschool classes related to reductions in cortisol for children attending Head Start preschool. It may be beneficial for implementation of arts-based or relaxation exercises at critical points of the preschool day such as midmorning to midafternoon to promote EF development throughout Head Start, and the present results will shed light on this possibility.

Present Study

The present study aims to add to the current scientific understanding of how cortisol relates to EF in young children facing economic hardship. The present study also aims to advance the scientific understanding of the relationship between cortisol and EF by assessing cortisol across the Head Start day, which will assist the ever-evolving implementation of early intervention for promoting positive outcomes for children facing poverty-risk. No published studies to date have assessed cortisol across the preschool day in relation to EF.
Research has demonstrated that most children in preschool settings experience a gradual increase in cortisol production from midmorning to afternoon opposed to the typical trajectory seen at home (Watamura et al., 2010). It is currently unclear if this finding is consistent across socioeconomic strata and further examination of this in relation to EF is critical for guiding intervention, as preschool may provide relief from stress in the home (Sajaniemiet, 2011) or risk accumulation of stress.

The current state of the literature suggests that higher basal cortisol predicts poorer performance on EF tasks of working memory and inhibitory control throughout early childhood in low SES contexts facing a broad range of poverty-related stressors (Blair et al., 2011; Raver et al., 2013). Therefore, I hypothesize that elevated basal cortisol will negatively predict EF performance on working memory and inhibitory control tasks. Additionally, research has demonstrated depressed basal cortisol in a subset of children who have experienced severe poverty-related stress, maternal depression, or trauma (Gunnar et al., 2011), yet few if any studies have been designed to address the impact on EF of blunted cortisol production across the day for young children facing economic hardship. Dysregulation of HPA axis activity in either direction poses risk for variation in gene activity and alterations in brain structure and function, with implications for cognitive and emotional development (McEwen & Gianaros, 2012). I hypothesize that a flattened or depressed trajectory of basal cortisol will predict poor performance on measures of EF as well.

The present study will examine cortisol across the preschool day in relation to performance on working memory and inhibitory control aspects of EF for children attending Head Start preschool. A sample of children attending Head Start was chosen as it represents our nation’s key investment for alleviating the impact of poverty circumstance on early childhood
development. Although Head Start is a means-tested program serving families of preschoolers facing economic hardship, few studies have focused on the relationship between EF and cortisol in this context, which is critical for future academic success and socioemotional development (Blair & Raver, 2016; O’Toole, 2017). Moreover, a Head Start preschool sample was selected due to my interest in critical developmental considerations of EF during early childhood, as this is a period of rapid EF growth that may be importantly impacted by stress. Additionally, I chose to measure EF and cortisol at the beginning of the preschool year, prior to the impact of the Head Start intervention.

To test the proposed hypotheses, I will measure cortisol at five time points across the preschool day and examine three indicators of cortisol functioning. One indicator is morning cortisol, measured just after preschool arrival. Morning cortisol will provide a start-of-day, baseline measure, consistent with some prior research (Berry et al., 2014; Blair et al., 2011). The second indicator is cortisol output across the preschool day, as measured by area under the curve with respect to ground (AUCg), which is standard for measuring cortisol output across the day (Olivera et al., 2015). The third indicator is profile of cortisol production, as determined by comparing child mean cortisol at start-of-day, midmorning, and at the end of the preschool day. Some research has indicated that the profile of cortisol across the day may hold importance unique from overall cortisol output across the day (Fekedulegn et al., 2007).

Previous research has documented the effects of cortisol dysregulation on working memory and inhibitory control aspects of EF (Blair et al., 2011; Raver et al., 2013). Therefore, I have chosen to include measures of these abilities to test the proposed hypotheses. Lastly, I have chosen to include controls for demographic variables such as, child age, birth-assigned sex, and family income, as previous research has demonstrated associations between these variables and
the proposed studies main constructs of physiological stress and EF (Blair et al., 2011; Lupien et al., 2001; Ursache et al., 2015).

Previous literature indicates a significant correlation between basal cortisol levels and executive function at alpha=.01 with basal cortisol levels accounting for a small effect size in EF ($np^2=.032$) (Blair et al., 2011). This suggests that a sample of greater than 1,000 would be needed for power of .80. However, Blair and colleagues (2011) established a stronger correlation ($r=-.56$, $np^2=.313$) between cortisol and EF as latent variables through the utilization of a structural equation model, and this suggests that a sample of 185 could support power of .80. Given constraints that correspond to the size of the collaborating Head Start preschool program, and a single year available for data collection, the present study is thought to serve as a realistic pilot.
Chapter 3: Method

Participants

Based on power analyses, the plan was to recruit participants from two schoolyear cohorts of children attending a local Head Start preschool for a pilot study of the constructs of interest. Due to the COVID-19 pandemic, only one year of data collection was possible for the present study, and thus the participants were drawn from a single schoolyear cohort and the sample size is half the size of what was planned for this pilot.

Participants were 50 children and their primary caregivers who were enrolled in a broader study of poverty and child development. The children attended a Head Start preschool in a small city in the Mid-Atlantic region of the US that was selected due to geographic proximity and the preschool’s interest in research collaboration. All children who attended the Head Start preschool were eligible to participate in the broader study. The present study included only those children who attended for a full day and therefore could provide cortisol samples across the day. This excluded a subset of children who attended special education programming in the afternoons.

Children ranged in age from 3 to 5 years old and the average age was 4 years old. Specifically, the mean age of child participants was 4 years and 1 month ($SD=6.32$ months). Regarding demographics, $54\%$ of children were male. The primary caregivers were biological mothers, biological fathers, and biological grandmothers. The mean family size was two adults (range =1-6, $SD=1.21$) and two to three children (range=1-5, $SD=1.11$). The breakdown of race/ethnicity of children and their primary caregivers was the following: $38\%$ Black or African American, $34\%$ Latinx or Hispanic American, $20\%$ White or European American, $4\%$ Multi-racial, $2\%$ Native American, and $2\%$ Asian American. In terms of language, $60\%$ were monolingual English language learners, and $40\%$ were dual language learners, with Spanish
being the most common dual language (38% of sample) and preferred by 12% of the child participants. Lastly, the mean family annual income was $12,410 (range = 0-42,500, \(SD=12,371\)).

**Procedure**

The present study was approved by the appropriate institutional review boards (IRBs). Recruitment took place at the time of Head Start enrollment or at pickup and drop offs at the start of the year, at which points trained research assistants provided parents with information about the study and gave them the opportunity to sign informed consent. At the same times, as well as via telephone follow up, parents were given opportunities to schedule interviews about their family circumstances. Trained research assistants conducted these 1hr interviews in person at the preschool or by telephone during September and October, and parents received compensation (a $20 gift card) for their participation. Information about family demographics and household chaos was collected as part of these interviews.

Child assent was obtained before all procedures involving children, and children received stickers or small prizes for their participation. Child cortisol was measured via salivary assay. Trained research assistants sampled children’s saliva at five time points across the preschool day (9:00AM, 10:30AM, 12:00PM, 1:30PM, and 3PM) on two days at the beginning of the school year. Children were randomly assigned to a schedule of cortisol assessment based on preschool class and those who were absent on the day of sampling, or whose parents reported potential interference from food or medication, were rescheduled for the same day of the week on the following week. Child EF was measured via standard laboratory-type tasks of working memory and inhibitory control. Researchers administered these tasks to children near the start of the preschool year, in a controlled testing environment room and following standardized procedures.
The working memory and inhibitory control tasks were administered separately to avoid participant fatigue. The 3 inhibitory control tasks were administered during 1 testing session.

**Measures**

*Demographic Interview*

As part of the family circumstances interview, parents or caregivers completed a demographic interview for caregivers (Ackerman et al., 2004) which includes standard demographic information including about the child’s family size, family income, birth-assigned sex, race/ethnicity, and age. Information about income was combined with information about family size and compared to federal poverty guidelines for the appropriate year to determine an income-to-needs ratio. A ratio of 1.0 represents the poverty line and 2.0 represents the threshold for economic disadvantage. This is found to be a reliable measure of income and has shown a test-retest reliability of .80 in a sample of low-income families with young children (Newland et al., 2013).

*Executive Function*

This study examined working memory and inhibitory control aspects of executive function. Working memory was assessed using one performance-based measure, whereas inhibitory control was assessed using three performance-based measures analyzed individually and as a composite score. Testing procedures were designed to promote child engagement as well as enjoyment. As such, EF tasks used were not intended to induce high levels of stress, rather moderate cognitive challenge.

*Working Memory (WM)*

The missing scan task modified for children ages 3-6 years was used to assess child working memory capacity (WMC; Roman, Pisoni & Kronenberger, 2014). In this task, children
are presented with and asked to identify twenty different miniature stuffed animals. The examiner sits facing the child with an opaque bag containing the twenty stimulus items (animals). The task begins with a test trial in which the child is presented with two animals (chosen at random) and instructed to “look carefully at these animals, when they go into the bag one of them will not come out.” Children are presented each memory set of stimuli for 10 seconds and instructed to recall the missing item approximately 2-3 seconds after the presentation of the full memory set. The span of stimuli presented increases by one each item trial for a total of 10 items (scores range from 1-10). The test is not administered if a child does not obtain a perfect score on the first test trial and testing is discontinued once a child fails to obtain a perfect score on any item. Research conducted by Roman, Pisoni and Kronenberger (2014) demonstrates that this MST has significant WM construct validity through feasibility (all participants we able to engage in test administration), and strong intercorrelations with well-established neuropsychological measures assessing WM represent concurrent validity  $r= .69$ ($p<.01$).

**Inhibitory Control (IC)**

The day-night Stroop task (Gerstadt et al., 1994) provided the first measure of IC. In this task, children are presented a black card with the moon and stars and asked to say “day” in response, and a white card with a sun and instructed to say “night”. This task consists of 16 trials and requires the child to remember two instructions whilst simultaneously inhibiting a natural verbal response (Gerstadt et al., 1994). The ability to use both memory and inhibition is dependent on the executive function capabilities in the prefrontal cortex of the brain (Diamond & Taylor, 1996).
The peg-tapping task (Diamond & Taylor, 1996) provided the second measure of IC. Children are instructed to tap a small wooden peg once in response to the examiner tapping the peg twice and vice versa (twice in response to once). Children are required to hold rules learned in their memory whilst inhibiting a natural response to mimic motor behavior (Diamond & Taylor, 1995). The study conducted by Diamond and Taylor (1996) indicates internal-consistency reliability between peg-tapping and day-night Stroop tasks as results show similar scores within the construct of inhibitory control. Additionally, inhibitory control performance in children ages 3-7 is concurrently valid with prefrontal cortex impaired population performance (Diamond & Taylor, 1995).

The bear/dragon task (Kochanska et al., 1996) provided the third and final measure of IC. This task is a modified version of “Simon Says” in which children are asked to selectively inhibit commanded actions based on the established rule to follow the “nice bear’s” commands but not the “naughty dragon”. This task includes 10 test-trials in addition to practice items and an opportunity for error correction. Studies show strong internal consistencies and developmental sensitivity (Kochanska et al., 1996; Carlson et al., 2004).

A z-score calculation was also used to create a composite score for these 3 inhibitory control measures. This calculation and inclusion of 3 performance-based measures of IC has been proposed to be a more accurate way of examining this skill in young children (Blair et al., 2011). Previous research from Blair and colleagues (2011) also included just 1 measure of working memory, noting challenges with assessing this construct in young children. The present study also included 1 measure of working memory, and this measure had demonstrated greater utility for examining working memory in this population (Roman et al., 2014).

Cortisol
Child cortisol was collected via salivary assay. Trained research assistants asked children to hold a swab under their tongue for about one minute to collect saliva. The swabs were checked by research assistants to ensure saturation and sampling was repeated if necessary. Saturated swabs were placed in conical tubes and stored at -20°C to prevent sample degradation until they were assayed in duplicate for cortisol concentration using an ELISA kit (Salimetrics, LLC, State College, PA). The test uses 25µl of saliva. It has a lower limit of sensitivity of .007mg/dl. The assay range is 0.012-3µg/dl. The average of the duplicate assays was used, with a standard criterion of no more than 7% error in agreement (Schwartz et al., 1998). In accordance with standard procedure, we set an exclusion criterion of > 10.0 for raw cortisol values.

**Analytical Plan**

The analytic plan included four stages of analysis. First, descriptive statistics were provided for all variables of interest, including raw cortisol values. A log transformation of these raw cortisol values was applied and descriptive statistics for the log values were provided. Furthermore, area under the curve with respect to ground (AUCg) was calculated to represent total cortisol output across the preschool day, and descriptive statistics were provided for this variable as well.

Second, based on cortisol levels at morning baseline (9am), midmorning (10:30am) and end of day (3pm), nonparametric analyses were used to examine various atypical trajectories of cortisol across the preschool day and classify children into the following groups with dichotomous coding: typical (within +1 or -1 SD of the mean at all time points = 0 with typical or not coded as 1 vs 0), high (more than 1 SD above the mean at two or more of these time points = 2 with high or not coded as 1 vs 0), low (1 SD below the mean at two or more of the time points = -2 with low or not coded as 1 vs 0), flat (more than 1 SD below the mean at initial time
point, but not at other two = -1 with flat or not coded as 1 vs 0), and other (any other profile = 1 with other or not coded as 1 vs 0). This type of categorization has proven useful in past studies of environmental risk and cortisol (e.g., Dozier et al., 2006). Dozier and colleagues (2006) utilized this analysis to identify high, low, and typical cortisol profiles across 3 time points across the entire day (morning, midafternoon, and bedtime) in a study examining HPA activity and foster care experience in young children. The present study varies from this prior work in its inclusion of flat and other profiles as well as the timing of cortisol collection to address key study questions related to cortisol and EF in the context of Head Start.

Third, zero-order correlations were used to examine the relationship between key demographic variables (i.e., child birth-assigned sex, age, family income, and race/ethnicity), the key predictor variables of child cortisol as indicated by: the 9am baseline measure, the AUCg measure of output across the preschool day, and the measure of cortisol profile or profile, and all three measures of child EF, as well as the inhibitory control or IC composite, which allowed for testing of study hypotheses related to cortisol profiles across the preschool day in relation to EF. It was hypothesized that atypical cortisol production across the preschool day (high, low or flat) would be associated with poorer EF performance.

Fourth, results of the zero-order correlational analysis were used to guide inferential statistics to examine relations between cortisol and EF, with appropriate demographic controls. Specifically, we expected to further examine relations between the following representations of cortisol and EF: cortisol at morning baseline (9am), cortisol output across the preschool day represented by AUCg, and the categorical representations of cortisol profiles or profiles.
Chapter 4: Results

Preliminary Analyses

Preliminary analyses included descriptive statistics for key variables of interest, followed by log transformation of cortisol scores to account for positive skew, classification of children based on various profiles of cortisol output across the day, calculation of area under the curve with respect to ground to represent cortisol output across the day, and construction of an index of inhibitory control. The mean raw cortisol value at the start of the preschool day was 0.44 ($SD = 0.44$). According to standard procedures, a log transformation was applied to correct for skew in this variable and log cortisol was used in further stages of analysis. The mean log cortisol value at the start of the preschool day was -0.56 ($SD = 0.28$). Means for raw and log cortisol values at each time of preschool day are displayed in Table 1. Mean raw AUCg was 24,409.09 ($SD = 21,824.00$) and log AUCg was 4.28 ($SD = 0.27$). Nonparametric analysis was used to categorize cortisol trajectories across morning baseline (9am), midmorning (10:30am) and end of preschool day (3pm). Child trajectory of cortisol production across these time points were classified into the following groups: typical (within +1 or -1 $SD$ of the mean at all time points, $n = 23$), high (more than 1 $SD$ above the mean at two or more of these time points, $n = 4$), low (1 $SD$ below the mean at two or more of the time points, $n = 6$), flat (more than 1 $SD$ below the mean at initial time point, but not at other two, $n = 6$), and other (any other profile, $n = 11$). Variables were then coded dichotomously, for example 1= flat and 0 = any other profile for further analyses.

Descriptive statistics of executive functioning measures were also calculated. Mean score on the missing scan working memory (WM) task was 1.31 ($SD = 1.73$). Mean scores on the inhibitory control (IC) measures are as follows; day-night Stroop task 6.19 ($SD = 5.13$), peg tapping task 5.54 ($SD = 5.54$), and bear/dragon task 7.44 ($SD = 1.96$). A $z$-score calculation was
used to create a composite score for the 3 inhibitory control measures. Participant scores ranged from 4 to 41 with a mean of 19.17 (SD = 10.17). Means and standard deviations for scores on executive functioning measures categorized by each cortisol trajectory group were also calculated and provided on Tables 2 and 3.

**Core Analyses**

Core analyses included *t*-tests to examine potential differences in EF for children with different cortisol profiles across the day, and bivariate correlational analyses. The plan was that these would be followed by multiple analyses of covariance or MANCOVA analyses where indicated. Independent *t*-tests were used to compare differences in working memory and inhibitory control performance for each cortisol profile group. Results of *t*-tests indicated that with *p* < .05, there were no significant differences between cortisol profile groups on either executive functioning construct measured (see Tables 2 and 3).

A Pearson zero-order correlational analysis was used to examine relationships between demographic and study variables. Results of this analysis revealed that no statistically significant correlations between key cortisol (AUCg, Basal/morning, and profile across the day) and executive functioning (inhibitory control tasks, IC composite, and missing scan task) variables with one exception: results indicated a positive correlation between flat cortisol trajectory and the missing scan working memory task *r*(43) = .39, *p* = .009. Regarding demographic variables, three statistically significant correlations were found. There was a positive relationship between child age and inhibitory control composite *r*(46) = .57, *p* = .001, as well as child age and the missing scan task *r*(43) = .38, *p* = .011. Additionally, higher familial income to needs ratio (i.e., greater family income per person in the household) was positively associated with typical cortisol trajectory *r*(48) = .49, *p* = .001.
In sum, results from bivariate correlational analysis examining relationships between key study variables and *t*-tests examining potential differences in EF performance for children with different cortisol profiles across the preschool day did not yield statistically significant findings related to study hypotheses. As such, these results did not suggest further analyses of covariance or MANCOVA.
Chapter 5: Discussion

The present pilot study examined morning cortisol levels and production of cortisol across the preschool day in relation to executive functioning ability for children attending Head Start preschool. The study was cut short by the COVID-19 pandemic, leading to a smaller sample size than planned- and even that planned sample was smaller than what would have been recommended based on power analyses- thus, these pilot results must be interpreted with caution. Overall, results did not show statistical relations between cortisol and child EF but did provide an interesting portrait of cortisol and EF within the context of Head Start preschool. As would be expected based on the literature (e.g., Blair et al., 2011), lower family income-to-needs ratios (indicating greater income impoverishment) were associated with atypical trajectories of cortisol across the preschool day. Understanding the impact of poverty circumstance and associated dysregulation within the physiological stress response system on executive functioning can inform intervention and programming in educational settings such as Head Start.

Cortisol across the Preschool Day

Child cortisol was collected at five time points across the preschool day and measured via salivary assay in accordance with standard procedures. See Figure 1 for graph displaying mean levels of cortisol across the day. Overall, children’s cortisol levels were greatest at the beginning of the preschool day. A relatively steep decrease was observed from the morning to midmorning collection time point, followed by a gradual increase throughout the remainder of the preschool day into the midafternoon. Mean levels of cortisol production across the day found in this study warrant further discussion when considering previous research on cortisol in early childhood care settings such as preschool, as well as the dearth of literature documenting cortisol profiles in Head Start samples.
A robust literature illustrates the impact of preschool settings on the typical diurnal profile of cortisol in middle and high-income populations. Psychosocial demands commonly experienced in these settings are thought to contribute to a slight rise in cortisol production across the midmorning rather than a gradual decline (Eliassan et al., 2012), which is aligned with the average trajectory demonstrated by this study. Considering the functional underpinnings of cortisol secretion at the neurobiological level, this profile may be generalizable. However, the impact of contextual risk (Berry et al., 2014) and protective factors within early childcare populations and settings (Rappolt-Schlichtmann et al., 2009), as well as limited existing research with these samples contribute to questions about the profile that might be expected for children of lower socioeconomic class (Eliassan et al., 2012; Hatifield, 2019). A study by Watamura and colleagues (2010) demonstrated rises in cortisol across the day at early childcare settings compared to the home in a sample with relative heterogeneity in terms of family income level, with 16% of families earning less than $25,000 per year. However, controls for family income were not included in the core analyses. This is consistent with many other studies examining the impact of early childcare settings on cortisol with even smaller representation of low-income populations and early childcare programs designed to support these children and families.

Relatively few studies have emphasized examining cortisol and early childcare settings in lower income populations. Findings from Berry and colleagues (2014) illustrate that participation in childcare settings in early childhood can relate to reduced basal cortisol at 4 years of age for children facing a multitude of risks and, in contrast, can relate to higher basal cortisol in children facing lower risk in a predominantly low-income sample. This finding partially aligns with a study completed by Rappolt-Schlitman and colleagues (2009) that demonstrated a decrease in cortisol production from 9:20am to 12:15pm for low-income preschoolers attending a high-
quality childcare program- a profile more typical than that documented for heterogeneous income samples of children in preschool context. These studies provide evidence that children experiencing economic hardship, and in particular severe poverty circumstance may experience some relief marked by cortisol reduction in early childcare settings, which contrasts with the average trajectory demonstrated in this study. Yet the Berry et al. (2014) study did not document cortisol levels while the children were in early childhood educational contexts, but rather measured basal cortisol levels at age 4 for children with different histories of attendance in early childhood educational programs. Also, the Rappolt-Schlichtmann et al. (2009) study did not collect cortisol across the afternoon period in early childhood education, which is the time of day at which the cortisol trajectory might tend to differ most for children in preschool versus at home (Eliassan et al., 2012; Hatifield, 2019).

Given the dearth of studies examining child cortisol levels across the preschool day for children facing poverty risks, the present study focused on a sample facing economic hardship makes a meaningful contribution. The pilot results of this study are aligned with those reported by Brown and colleagues (2021) in suggesting increasing cortisol levels across the period from midmorning to midafternoon for children attending Head Start preschool. These results generally match the findings with heterogenous income samples of children and suggest a need to thoughtfully consider the impact of early childhood educational contexts on HPA-axis functioning, including for children who already face the burden of poverty-related stress.

However, this result from the pilot study should not be interpreted as one that counters the previous findings by Berry et al. (2014) and Rappolt-Schlichtman et al. (2009). Rather, the present results are thought to reflect the complex portrait of HPA-axis functioning for young children in early childhood educational contexts. The impact of early childhood care settings on
the daily trajectory of cortisol varies greatly, and likely is influenced by cumulative and contextual risk, as well as the interactive effects of environment-specific protective factors in the home, community, and classroom.

Additionally, this pilot study contributed by identifying within Head Start preschool divergent cortisol profile groups that have been documented in other settings by prior research teams. For example, this study highlighted a traditionally underrepresented subset of participants with a flattened trajectory in which morning cortisol was low and remained 1 SD above the mean for the following two time points. This profile across the day has been found for preschoolers facing exceptionally high or cumulative poverty risk and severe family financial strain (Badanes et al., 2015; Zalewski et al., 2012). This subset of children represents a critical population of need and further examination as this trajectory is associated with attenuated cortisol reactivity to stressors (Badanes et al., 2015) and increased allostatic load, which are strong predictors of poor physical and mental health outcomes.

This pilot study adds to this line of research in several notable capacities. Overall, it provides a unique framework and design that is sensitive to measuring and analyzing cortisol within the population of interest. In contrast to Badanes and colleagues (2015) and Zalewski and colleagues (2012), the present study collected cortisol in the preschool classroom and at specific time points of interest (midmorning across midafternoon), whereas these previous studies had collected cortisol in a laboratory or home setting at just two times—before and after school. These prior studies noted the timing and setting as limitations, by which key information related to how hyopcortisolism and blunted reactivity may have been missed. The design of the present study and identification of preschoolers with this cortisol profile adds to these previous findings in suggesting the importance of studying children whose blunted cortisol levels likely are
influencing their Head Start preschool experiences. Additionally, the design of the present study seems to have been sensitive to complexities regarding how HPA axis functioning is impacted in preschoolers facing varying levels of economic hardship. This is evidenced by the statistically significant finding that lower income-to-need ratios were associated with atypical cortisol trajectories. This matches the general finding that income impoverishment relates to HPA axis dysregulation (McEwen & McEwen, 2017). Therefore, it is believed that the design presented in this pilot study demonstrates promising utility for replication with larger sample sizes for testing key study hypotheses related to executive functioning.

**EF**

In the present study, children’s EF was measured using performance-based tasks previously and successfully used to assess inhibitory control and working memory EF constructs. Mean scores demonstrated in this study seem to be consistent with those obtained in prior studies with similar samples, such as that by Blair, Raver, and colleagues (2011, 2013), who assessed these EF constructs in a large, population-based study of predominantly low-income children at approximate ages of 36 months and again at 48 months. There are small and apparent differences in EF performance when comparing the present study to this prior work. However, these differences are likely explained by variations in the age range of sample, choice of working memory measurement tool, and exclusionary criteria for scoring procedures.

In the prior studies conducted by Blair, Raver, and colleagues (2011, 2013), working memory was assessed using 1 span task and inhibitory control was measured using three tasks which included a Stroop, go no-go, and Simon task. Scores on IC tasks were combined for analysis and performance on measures were presented as average percent correct in these studies. At 36 months, WM was .27 and IC was .66. At 48 months, WM was .56 and IC was .52. Scores
were moderately correlated with one another at each age-point (Blair et al., 2011; Raver et al., 2013). The age range for the present study was 3-5 years with a mean age of 49 in months. Mean scores on WM and IC tasks, converted to percentage correct for comparison to prior work are .13 for WM task and .50 for IC tasks combined. Like in the previous work, scores from the present study on various EF tasks and constructs were statistically correlated, which is in line with theory and longstanding research documenting the interrelation of EF constructs (Miyake, 2001).

The stark difference between the WM scores of this pilot study and those demonstrated by Blair and Raver is likely explained by differences in the chosen measurement tool and the presentation of performance as percentage correct. In terms of measurement tools, the span task used in this previous work included 5 test-trials, whereas the missing scan task (Roman et al., 2014) used in the present study included 10 test-trials. The composition of trials, namely the length and timing of trials for both the present and prior scan task were the same in the beginning, but varied as the task went on. The span task used by Blair and Raver consisted of one, one-item trial, followed by two, two-item trials, then two, three-item trials. As such a mean percent correct of .27 would indicate that participants are consistently able to respond accurately to a span of one stimulus item, and a percent correct .56 would mean the same for at least one span of two stimulus items. The missing scan task used in the present study also began with a one-item trial followed by a two-item trial. Therefore, a mean percentage correct of .13 would indicate consistent ability of participants to respond accurately to a span of one stimulus item and some ability to identify a span that includes two stimulus items.

After accounting for differences in measurement composition, the observable differences that do remain in scores when comparing the study by Raver and colleagues (2013) and the present study could partially be explained by the inclusion of a range of age in the present study
versus all participants being 48 months old. Additionally, discontinue criteria varied from the present study in that participants in Raver and colleagues (2013) needed to complete 75% of trials for scores to be counted, excluding 12% of children’s scores. This was not the case for the present study as it was intentional to explore the feasibility of the relatively new WM task used (Roman et al., 2014), which had been validated in a sample of children with heterogenous family income levels- in the present study, all scores were counted in the mean. Overall, this task demonstrated validity with the present sample facing economic hardship, and yielded mean scores that are generally consistent with those documented by prior work using different WM measures with populations experiencing economic hardship.

IC mean performance found in this study was very similar to IC performance found by Raver and colleagues (2013) who examined EF performance at 48 months of age. Interestingly, in the work of Blair, Raver, and colleagues (2011, 2013) a decrease in mean IC performance was observed from 36 to 48 months. At 36 months, more than half of participant scores on IC measures were not included due to the exclusionary discontinue criteria 75% completion noted above (Blair et al., 2011). More than 90% of participant IC scores were included at 48 months of age (Raver et al., 2013). Therefore, it is plausible that the decrease in mean IC scores could be explained by this marked inclusion of participants that could not attend to test materials, understand directions, or demonstrate some level of IC at 36 months. Otherwise stated, it could be the case that these participants were more likely to score lower on IC tasks, and the large number of these participants brought the average down at a more powerful rate than participants whose scores were used at 36 month’s growth could account for. Therefore, despite the observed decrease in mean performance longitudinally, results could theoretically be indicative of positive EF development. An alternative explanation is that the accumulation of time spent in poverty
circumstance during a particularly sensitive developmental period for IC, can lead to regressive outcomes. Results from the present study indicating a statistically significant positive relationship between child age and EF align with the former, as well as theory on typical cognitive and EF development.

However, the consistency between mean scores found in the present study and previous work further supports the existence of a clear disparity in EF across SES strata. Moreover, taken together, findings from the present study and previous work emphasize the importance of considering child age and the specific EF construct when examining poverty risk and EF development. As previously mentioned, EF shows rapid development during early childhood (Garon et al., 2008), and the timing of the acquisition and honing of specific skills or constructs within EF during this developmental period varies (Kolb & Wishaw, 1998; Miyake, 2001). Therefore, it may be the case that more latent EF skills such as executive planning (Miyake, 2001) are more susceptible to the accumulation of poverty-related stress throughout early childhood.

**Cortisol and EF**

Results of this pilot study did not show expected statistical associations between EF and cortisol variables of particular interest. Indeed, the one statistically significant finding was a statistical zero-order correlation between flat cortisol profile and higher WM scores- an unexpected finding. Notably, this finding could have been spurious, given the number of relations examined. A post-hoc test to correct for multiple correlations examined at once such as a Bonferroni procedure was not completed due to problems present in this study related to statistical power. In fact, these procedures have been shown to worsen the issue of low statistical power (Nakagawa, 2004). It also is possible that the association could have been driven by the
combined impact of multiple other profiles, given that flat was compared against all other groups (e.g., low, high, and typical). Given that this finding was not expected and ascertaining whether it was spurious may raise further issues, caution in interpreting this finding is advisable.

In considering potential explanations for this finding, were it not spurious or driven by the combined impact of multiple other profiles, there are a few potential explanations for a statistical relation between a flat profile and higher scores on the WM scan task was found. One explanation stems from design choices of the present study regarding the collection time point of morning cortisol. Basal or morning cortisol in prior work such as that of Blair and colleagues (2011) had been collected just after awakening, whereas a morning measure of cortisol was collected upon school entry at 9am in the present study. Additionally, the time in which children woke up on the day of cortisol collection in this study was not controlled for analysis. As such, it is possible to speculate that children demonstrating a flat profile across the preschool day may have woken up in the home setting considerably earlier than peers. Therefore, a flat profile may not have been indicative of significantly diminished basal cortisol, which was a key identifier of a flat profile in this study. Rather, it could have been indicative of something about home routines or family functioning that posed an advantage for children in terms of the WM aspect of EF.

Also, little is known about the relation of cortisol output across the preschool day and EF for lower income children, which concerns interpreting cortisol levels at the subsequent timepoints of 10:30am and 3pm for the flat profile group. Prior work had linked immediate increased cortisol activity in response to a challenging task followed by immediate down-regulation of cortisol production to higher performance on EF tasks in a Head Start sample (Blair et al., 2005). The present study was not designed to examine cortisol reactivity and regulation in
this fashion, and rather was designed to capture patterns of atypical cortisol activity that may naturally present in the context of Head Start in relation to EF. This design choice was novel for studies of EF for children in Head Start, which complicates comparisons with past findings. It is possible that a flat profile relative to other Head Start students was not indicative of a pattern of harmful blunted cortisol reactivity and difficulties with down-regulation. In fact, recent research highlights the importance of individual subjectivity and history, as well as the phenomena of “saving resources” when considering physiological stress response and cognitive performance (Pleiger & Reuter, 2020). The concept of saving resources suggests that withholding or regulating cortisol reactivity during less stressful or challenging times may be adaptive for tasks that demand greater EF. Therefore, a flat profile across the preschool day may be helpful for performing well on a task assessing WM. Although these possibilities warrant consideration, the current study’s hypotheses were grounded in current evidence.

The current state of the literature across multiple disciplines suggests that dysfunction in the HPA axis partially explains greater EF difficulties for children in low-income contexts facing a broad range of poverty-related stressors (Blair & Raver, 2016; McEwen & Gianaros, 2012; Wagner et al., 2015). In by far the most comprehensive line of research on this topic to date, higher basal cortisol predicted poorer performance on WM and IC throughout early childhood (Blair et al., 2011; Raver et al., 2013). Therefore, a statistically significant negative association between morning cortisol and EF performance was expected. Additionally, given the integration of previous research on neurodevelopmental and cognitive consequences of high allostatic load and the assumption that high basal cortisol across early childhood increases the overall output of cortisol throughout the day, it was predicted that high AUCg would be associated with poorer EF performance. Hypotheses were also developed to account for the unique consideration of the
context of preschool’s impact on cortisol and EF, and the potential for a subset of children to demonstrate hypocortisolism or blunted reactivity (Badanes et al., 2015; Gunnar & Vazquez, 2001; Zalewski et al., 2012). The creation and examination of cortisol profiles across the day allowed for testing these hypotheses. It was expected that participants demonstrating high profiles of cortisol exceeding typical elevations that may have occurred due to challenges related to the preschool context at key time-points would score lower on EF tasks. Lastly, it was expected that a flattened or depressed trajectory would be associated with poorer EF performance.

There are several potential explanations as to why expected statistically significant relations between cortisol and EF were not found in this study worth noting. Foremost, are sample size limitations resulting from working with a single Head Start sample, which were exacerbated by the COVID-19 pandemic. Given the dynamic nature of how the context of poverty effects the HPA axis and cortisol production in relation to the construct of EF during the developmental period of early childhood, the relatively small sample size likely explains why significant associations were not found. This pilot study was designed to account for the various ways HPA axis dysfunction can manifest in the context of early childhood poverty for a sample attending Head Start. However, the design of cortisol collection diverged from previous research linking cortisol to EF performance. As previously mentioned, cortisol was not collected just after awakening where a clearer picture of high allostatic load may be present. Additionally, cortisol reactivity and regulation were not directly assessed in response to a stressor or cognitively challenging stimuli. It may be that this aspect of HPA activity is particularly important for healthy brain development and associated EF skills during early childhood. Indeed, a recent longitudinal study by Feola and colleagues (2020) linked greater cortisol reactivity to poorer EF
performance in middle school and this relation was mediated by prefrontal cortex thickness. Lastly, this study only included measurements for two EF constructs, which was largely based on previous examples demonstrated in the literature. It is possible statistically significant associations between EF and cortisol were not found because of this measurement choice. Despite limitations and the absence of statistically significant findings aligned with study hypotheses, this pilot study provides meaningful future directions for research investigating cortisol and EF in a setting that had not previously been explored.

**Limitations and Future Directions**

To address the primary limitation of this pilot study, future research should include a greater sample size to test study hypotheses. Based on prior literature and the results of the present study, the presence of subgroups of children with different cortisol profiles is very likely. It will be imperative for future studies to include a large sample size to test relations to EF for each subgroup as these relations may vary. This study was intentional in its examination of cortisol and executive functioning performance in a sample of children facing economic hardship who attend Head Start. However, this specific focus likely limited findings when considering the greater impact of poverty circumstance. Although there are many advantages to studying HPA functioning and EF within a sample facing poverty-related risk, future studies might also examine these variables in a sample in which household income is heterogeneous.

Moreover, future studies might choose to study children longitudinally, such as across the school year or through the transition to kindergarten, or include a wider age range in sample. A future study replicating the design of the present pilot study longitudinally, could provide critical knowledge related to how poverty circumstance impacts HPA axis dysfunction and the development of EF skills during early childhood. Such a study could clarify findings related to
the attenuation hypothesis proposed by Susman (2006) by studying cortisol profiles across the day longitudinally. Moreover, measuring cortisol profiles across preschool days longitudinally would add instrumental knowledge related to the impact of early childcare settings on cortisol for children facing economic hardship. Lastly, a future study replicating the design of this pilot study longitudinally or with a greater age range of participants could account for differences in the development of particular aspects of EF that may be more or less sensitive to certain cortisol profiles across the preschool day.

Limitations that are consistent with a correlational design are present. As such, correlations found in the present study do not assume causation. Moreover, statistically significant relationships not found may have been impacted by confounding variables not measured in this study. There are many contextual risks associated with poverty circumstance (Evans, 2004), and risks such as instability or chaos in the home and to exposure to adverse experiences such as neighborhood violence impact the development of executive functioning skills (Evans, 2002; Brown et al., 2013). Additionally, there are contextual protective factors that may promote resilience and have potentially masked relations in the present study such as positive parenting (Blair et al., 2011) and friendships in the community (O’Toole, 2017). Future studies investigating HPA axis activity and executive functioning abilities in Head Start populations should aim to capture and integrate contextual risk factors associated with economic hardship and poverty circumstance as well as factors that promote resilience in the individual.

The current study is also limited by measuring executive functioning solely through laboratory performance-based measures. While measures used in this study are considered well-established, reliable, and valid in assessing the construct of EF and skill components, they lack external validity and perhaps miss what EF looks like in settings such as the preschool
classroom. Future studies examining the relationship between EF and cortisol in Head Start should utilize report-based measures in combination with performance-based tasks. Indeed, a recent study by Brown and colleagues (2023) published after the execution of the present pilot demonstrated relations between high basal cortisol and production across the Head Start preschool day and teacher-reported EF difficulties. Additionally, future studies should measure performance on EF constructs that have not been emphasized in prior literature to account for considerations of EF development and cortisol across early childhood noted. For example, a modified version of the Tower of Hanoi task (Simon, 1975), has been shown to be a feasible and valid measure of executive planning for children 3-6 years of age (Miller, 2011).

Another limitation worth noting involves the collection time points of cortisol throughout the preschool day. The trajectory of cortisol production follows a diurnal profile peaking just after waking and reaching its lowest point before bedtime. The current study utilized five time point collections during the preschool day intentionally. However, cortisol was not collected just after awakening when it is expected to be at its peak (Pruessner et al., 1997) and might provide a clearer picture of whether atypical allostatic load is present (Badanes et al., 2015; Blair et al., 2011). Future studies might investigate the trajectory of cortisol throughout the day beginning first thing in the morning to obtain a fuller picture of cortisol trajectory before, during, and after the preschool day.

**Implications for Research**

Overall, this pilot study is believed to contribute a strong template for future studies with a larger sample size. It is the first study to examine cortisol across the day in relation to performance-based measures of EF in a Head Start sample. The design used and findings identifying subgroups of cortisol profile profiles highlights important gaps in the current state of
the literature relating to complexities of HPA axis dysfunction and the impact of early childcare settings on cortisol for young children facing economic hardship. The statistically significant association found between income and atypical cortisol profiles is supported by studies across a range of disciplines and this finding in comparison to others experiencing economic hardship and attending Head Start provides new insight to this prior work. Answers related to how these cortisol profiles across the day relate to EF were most likely not able to be found due to noted limitations. However, the integration of prior literature and observations presented by this pilot study warrant continued exploration of cortisol and EF in this setting to build upon this study and relatively novel area of research and further inform policy and practice.

**Implications for Policy and Practice**

Average performance on measures of EF in this study were consistent with prior work with similar populations (e.g., Blair, 2011), and these scores are markedly different from those found for middle-income samples (e.g., Best, 2011). This demonstrates the existing disparity in EF across socioeconomic strata and supports the continued efforts of policy makers and practitioners in early educational and intervention settings to further address this concern as EF holds critical importance for educational success (Best et al., 2011) and psychological well-being (O’Toole, 2017). There are a number of early childhood intervention programs that have demonstrated a positive impact on child EF and/or self-regulation.

One such example is the Chicago School Readiness Project (CSRP), which was implemented in a Head Start context and designed to target difficulties with self-regulation and EF (Raver et al., 2008). This program included comprehensive teacher training through professional development seminars and in-vivo consultation from mental health professionals in the classroom, as well as the provision of direct mental health services given to children
identified as high-risk (Raver et al., 2008). Significant improvements in EF assessed by performance-based measures of working memory, inhibitory control, and cognitive flexibility, were demonstrated at the end of the Head Start year (Raver et al., 2011). Moreover, a follow-up study conducted by Watts and colleagues (2018) suggested that long-term benefits in self-regulation and EF were present. Findings demonstrated as a result of this program, emphasize the importance of targeting poverty-related stress at the individual, interpersonal, and environmental level. In fact, a meta-analytic study conducted by Duncan and colleagues (2015), demonstrated that early intervention programs targeting improvements in many aspects of cognitive development were much more successful in the long-run when intervention addressed environmental stress or risk, as opposed to interventions or programs that only emphasized skills-based learning. The Head Start REDI program (Bierman et al., 2008) and the “Put Your EF Glasses On” program from (Kellen et al., 2023) are a few other examples of early educational programs developed and shown to effectively support EF development for young children facing economic hardship.

In addition to the development of EF abilities throughout early childhood and the lifespan, poverty-related stress and associated HPA axis dysfunction marked by irregularities in cortisol production pose mental and physical health related risks (Badanes et al., 2015; McEwen et al., 2013). As such, the statistically significant association between family income-to-needs ratios and atypical cortisol profiles present in this Head Start sample adds to literature suggesting the need for early intervention to reduce stress levels for children in poverty. It must be noted that early intervention will remain limited and largely reactionary, as long as poverty and related stressors exist. As such, there is an essential need for policy that effectively reduces or even eliminates poverty and related stressors.
Implications for clinical practice involve the therapeutic work of mental health professionals working with children and families experiencing economic hardship. In the individual therapy context, there must be continued focus for teaching and practicing self-regulatory, distress tolerance, or relaxation-based activities prior to engaging in therapeutic work that is cognitively demanding or emotionally evocative. This is illustrated in models of treatment for trauma-related disorders such as TF-CBT. However, it may be the case that children experiencing poverty-related stress would benefit tremendously from more practice over an extended duration of time or sessions. Moreover, it is important for clinicians to consider integrating these techniques for modalities that may be considered less cognitively demanding or stress-inducing for general clinical populations such as relationship and social skill building. Practitioners must also treat and aim to reduce poverty-related stress in the individual’s ecological system. For example, treatment may include parent training around ways to increase structure and reduce household chaos to alleviate or prevent HPA axis dysfunction. Clinicians must also be prepared to advocate for or connect families to resources in the community when systemic barriers affect this work.

Implications also concern early educational programs designed to reduce the negative impacts of economic hardship and promote equality in academic outcomes. Research has demonstrated that the integration of mindfulness, yoga, or arts programming in the educational setting can reduce stress at the physiological level (Bultzer et al., 2015; Brown et al., 2016). These practices could be implemented at critical times of the preschool day such as the midmorning and would be particularly beneficial for children at risk for demonstrating a high or flat cortisol profile. Additionally, early educational programming should consider environmental conditions that may mitigate or exacerbate the added stress of the preschool context that is
experienced by some students. For example, early educational programs should consider a smaller group setting or opportunities to spend time with a teacher or professional that a child has a positive rapport with during this sensitive time period of the preschool day.

**Summary and Conclusion**

The present pilot study examined morning cortisol levels and production of cortisol across the preschool day in relation to executive functioning ability for children attending Head Start preschool. Results did not demonstrate statistically significant relations between cortisol and EF. However, results are believed to provide meaningful information regarding cortisol and EF within the context of Head Start preschool, though these pilot results must be interpreted with caution due to limitations related to design choices and the unexpected impact of the COVID-19 pandemic. Overall, it is hoped that this pilot provides a foundation for future studies aiming to increase our understanding of the impact of poverty circumstance and associated dysregulation within the physiological stress response system on executive functioning to inform intervention and programming in educational settings such as Head Start.
Table 1

*Means and Standard Deviations for Cortisol Samples by Collection Time Point (N=50)*

<table>
<thead>
<tr>
<th>Cortisol</th>
<th>9:00 am Morning</th>
<th>10:30am Midmorning</th>
<th>12:00pm Noon</th>
<th>1:30pm Afternoon</th>
<th>3:00pm End Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>0.44 (0.44)</td>
<td>0.25 (0.22)</td>
<td>0.28 (0.29)</td>
<td>0.34 (0.36)</td>
<td>0.36 (0.53)</td>
</tr>
<tr>
<td>Log</td>
<td>-0.55 (0.28)</td>
<td>-0.75 (0.23)</td>
<td>-0.73 (0.28)</td>
<td>-0.61 (0.32)</td>
<td>-0.63 (0.35)</td>
</tr>
</tbody>
</table>
Table 2

*Independent Samples t-tests for Cortisol Groups on Inhibitory Control Composite Scores*

<table>
<thead>
<tr>
<th>Cort. Group</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>19.0</td>
<td>8.87</td>
<td>-.108</td>
<td>46</td>
<td>.915</td>
</tr>
<tr>
<td>Not Typical</td>
<td>19.32</td>
<td>8.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>18.5</td>
<td>4.65</td>
<td>-.136</td>
<td>46</td>
<td>.893</td>
</tr>
<tr>
<td>Not High</td>
<td>19.22</td>
<td>10.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>19.5</td>
<td>13.1</td>
<td>.085</td>
<td>46</td>
<td>.933</td>
</tr>
<tr>
<td>Not Low</td>
<td>19.11</td>
<td>9.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>22.17</td>
<td>13.8</td>
<td>.769</td>
<td>46</td>
<td>.446</td>
</tr>
<tr>
<td>Not Flat</td>
<td>18.74</td>
<td>9.69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>17.67</td>
<td>12.13</td>
<td>-.487</td>
<td>46</td>
<td>.629</td>
</tr>
<tr>
<td>Not Other</td>
<td>19.51</td>
<td>9.81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3

*Independent Samples t-tests for Cortisol Groups on Missing Scan Task Scores*

<table>
<thead>
<tr>
<th>Cort. Group</th>
<th>$M$</th>
<th>$SD$</th>
<th>$t$</th>
<th>$df$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>.74</td>
<td>.93</td>
<td>-2.182</td>
<td>43</td>
<td>.056</td>
</tr>
<tr>
<td>Not Typical</td>
<td>1.73</td>
<td>.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>.50</td>
<td>1.0</td>
<td>-.982</td>
<td>43</td>
<td>.332</td>
</tr>
<tr>
<td>Not High</td>
<td>1.39</td>
<td>1.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.17</td>
<td>1.47</td>
<td>-.217</td>
<td>43</td>
<td>.829</td>
</tr>
<tr>
<td>Not Low</td>
<td>1.33</td>
<td>1.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>3.00</td>
<td>2.82</td>
<td>1.64</td>
<td>43</td>
<td>.154</td>
</tr>
<tr>
<td>Not Flat</td>
<td>1.05</td>
<td>1.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1.80</td>
<td>1.93</td>
<td>1.014</td>
<td>43</td>
<td>.367</td>
</tr>
<tr>
<td>Not other</td>
<td>1.17</td>
<td>1.67</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Figure 1. Cortisol Levels Across the Preschool Day**

Note: Cortisol values are raw. These descriptive statistics do not account for covariates.
References


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